SELF ORGANIZED CRITICALITY IN STRUCTURAL ELEMENTS WITH FRICTION

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Prior observations of deployed space structures indicated both quasi-static creep and spontaneous vibrations can be expected at optical scales of deformation [1,2]. One potential explanation is that this unusual behavior was due to instability in the frictional interfaces in the joints of the structures. Friction interfaces exhibit similar quasi-static and dynamic behavior in a number of different applications. Whether or not friction is responsible for the quasi-static creep and/or the spontaneous vibrations recorded in deployable joint-dominated structures has never been confirmed, either by direct measurement or by theoretical extrapolation. This paper explores the possible theoretical origin of such observations, should frictional instability be the root cause.

The concept of self-organized criticality was introduced by Bak et al. [3], and was quickly adopted by the geomechanics [4] community as a potentially powerful tool in the understanding of crustal mechanics. The underlying concept is that some mechanical systems, due to internal mechanics, reach a critical state. From this state, small perturbations can result in a chain reaction, affecting any number of elements within the system. The model introduced by Burridge and Knopoff [4] is a lumped parameter model of the interface between two surfaces in frictional contact. The contact of two friction interfaces occurs over multiple discrete locations, much smaller than the nominal size of the interface (see Figure 1). The reactions from one asperity to the next govern the critical nature of the interface. As asperities slip, the energy released is partially transferred to the surrounding asperities, potentially leading to large scale slipping and vibration in a structure containing these interfaces. This model has been adapted for use in the description of frictional joints.

The purpose of this research is to determine whether or not the interface mechanics seen at the asperity level can account for the creep behavior and dynamic anomalies seen in previous experiments. The model experiences creep-like mechanics and nano-lurch response, similar to the quasi-static response measured in friction interfaces and deployed structures to date. Additionally, the model allows for the storage and spontaneous release of strain energy similar to earthquakes seen in crustal mechanics and deployed joint-dominated structures.

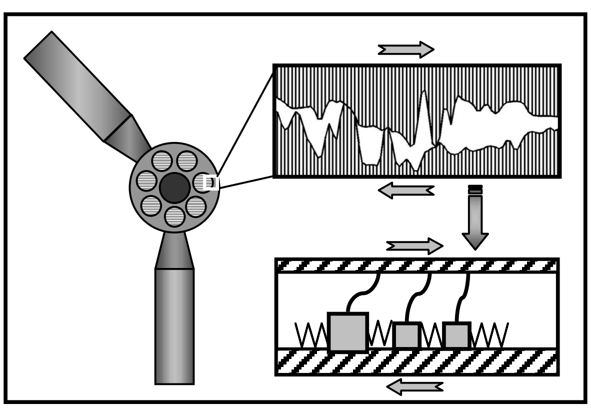

Figure 1: Burridge-Knopoff model extended to frictional joints.

References

[1] L. Hardaway, and L. Peterson, "Nanometer-Scale Spontaneous Vibrations in a Deployable Truss Under Mechanical Loading," *AIAA Journal*, v. 40, no. 10, p. 2070, 2002.
[2] M.B. Levine, "Microdynamic Behavior of a Joint Dominated Structure On-Orbit," 40th Annual Structures, Structural Dynamics, and Materials Conference, St. Louis, 1999
[3] P. Bak, C. Tang, and K. Wiesenfeld, "Self-Organized Criticality," *Physical Review A*, Vol. 38, No. 1, 1988
[4] R. Burridge, and L. Knopoff, "*Bulletin of the Seimological Society of America*", Vol. 57, p. 341, 1967